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http://dx.doi.org/10.1289/EHP73

Received: 7 March 2016
Revised: 12 July 2016
Accepted: 26 July 2016
Published: 26 August 2016

Environ Health Perspect DOI: 10.1289/EHP73
Advance Publication: Not Copyedited

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Acknowledgements

The study was supported by the Public Welfare Research Program of National Health and Family Planning Commission of China (201502003 and 201402022), Cyrus Tang Foundation (CTF-FD2014001), State Key Basic Research Program(973) Project (2015CB553404), China Medical Board Collaborating Program (13-152), ZhuoXue Plan for the funding support by Fudan University (Nr. JJF201049) and the fund by the Shanghai 3-Year Public Health Action Plan (GWTD2015S04).

Conflict of interests

The authors declared no conflicts of interests.

ABSTRACT

Background: Practical approaches to protect the individual health from ambient particulate matter are urgently needed in developing countries. The evidence is limited on the health benefits of wearing particulate-filtering respirators.

Objectives: To evaluate the short-term cardiovascular health effects of wearing respirators in China.

Methods: A randomized crossover trial was performed in 24 healthy young adults in Shanghai, China in 2014. The subjects were randomized into 2 groups and wore alternately a particulate-filtering respirator for 48 hours with a 3-week washout interval. Heart rate variability (HRV) and ambulatory blood pressure (BP) were continuously monitored during the 2nd 24 hours in each intervention. Circulating biomarkers were measured at the end of each intervention. Linear mixed-effect models were applied to evaluate the effects of wearing respirators on health outcomes.

Results: During the intervention periods, the mean daily average concentration of $PM_{2.5}$ was 74.2 $\mu g/m^3$. Compared with the absence of respirators, wearing respirators was associated with a decrease of 2.7 mmHg (95% confidence intervals(CI): 0.1, 5.2 mmHg) in systolic BP and increases of HRV parameters, including 12.5%(95% CI: 3.8%, 21.2%) in high frequency(HF) power, 10.9%(95% CI: 1.8%,20.0%) in the root mean square of the successive differences, and 22.1%(95%CI:3.6%,40.7%) in the percentage of successive NN intervals differing by>50ms. The presence of respirators was also associated with a decrease of 7.8% (95% CI: 3.5%, 12.1%) in the ratio of low frequency(LF)/HF power.

Conclusions: Short-term wearing of particulate-filtering respirators may obtain cardiovascular benefits in improving autonomic nervous function and reducing BP.

1. Introduction

Cardiovascular health hazard is one of the primary health risks associated with air pollution exposure (Donaldson et al. 2013). A number of population-based epidemiological studies have demonstrated that short-term exposure to air particulate matter (PM) is associated with reduced heart rate variability (HRV) (Baccarelli et al. 2008; Ren et al. 2010), increased blood pressure(Hampel et al. 2011) and inflammation levels (Liu et al. 2009), all of which can act as indicators for potential adverse cardiovascular health effects. PM with aerodynamic diameter <2.5 μm ($PM_{2.5}$) is particularly related with the cardiovascular health damage and can act as a stimulus to trigger local cytokine production and systemic inflammation (Schins et al. 2004).

In developing countries where population size is large and air pollution levels are high, the disease burden of $PM_{2.5}$ is more severe than that in North America and Europe. The Global Burden of Disease (GBD) study estimated that ambient PM ranked fourth among all risk factors in China in 2010, contributing nearly 8% of the total disability-adjusted life years (Yang et al. 2013). Given that it is not easy to cut the emission of air pollutants in a short time in developing countries, approaches that can reduce individual exposure are considered to be practical and cost-effective to protect the public health from ambient PM. These approaches are urgently needed in high-polluted countries such as China and India. Previous studies have reported the health benefits associated with the use of indoor air purifiers and oral supplements (Chen et al. 2015a; Romieu et al. 2008). As one of the most convenient and affordable measures, wearing particulate-filtering respirators is becoming increasingly popular in

China, especially in outdoor environment. However, the evidence is limited on its health benefits (Langrish et al. 2009; Langrish et al. 2012).

Therefore, we designed a randomized controlled crossover trial to evaluate the potential cardiovascular benefits associated with wearing a particulate-filtering respirator in a group of healthy young adults in Shanghai, China. We examined blood pressure (BP), HRV and circulating biomarkers which were considered as important pathways by which PM leads to adverse cardiovascular outcomes (Brook et al. 2010).

2. Materials and Methods

2.1 Study design and participants

We conducted a randomized crossover trial in a group of healthy college students at Fudan University, Shanghai, China, during the period from Mar 21st to April 13th, 2014. The entire study was completed within one month to avoid potential confounders due to long-term and seasonal trends of health outcomes.

Initially, we recruited 30 students with no history of tobacco smoking (never smokers) or alcohol addiction, no clinically diagnosed chronic cardiopulmonary diseases (including asthma, rhinitis et al.) and no recent infections. Since all participants lived in the campus dormitory rooms (a typical dormitory room is shared by 4 or 6 persons) and studied within the campus, they were seldom exposed to environmental tobacco smoking since smoking was banned in any public places in the campus.

The participants were equally randomized into 2 groups and wore alternately a

particulate-filtering respirator for 48 hours with a 3-week washout interval. Specifically, in the 1st intervention period, one group wore the designated high-efficiency particulate-filtering respirators for 48 hours as the intervention group, while the other group behaved as usual (as the control group). After a 3-week wash-out interval, the two groups exchanged their roles and completed the 2nd intervention period. HRV and ambulatory BP were continuously monitored during the 2nd 24 hours of each intervention. Blood samples were collected at the end of each intervention period around the same time to measure the circulating biomarkers of inflammation, vasoconstriction and coagulation.

Participants were instructed on how to wear the respirators and fit with the faces closely and comfortably. Every time they took off and/or wore the respirator, the standard wearing positions were required. During the interventions, they acted as usual, but were mandated to have a one-hour walk along the road outside the campus to simulate the regular traffic exposure pattern. For the intervention group, wearing the respirators was required all the time outdoors, and as much as possible indoors. The subjects were asked to record their feelings of fitness and comfort on the use of respirators (a scale score from 0 to 10 referring to the worst fitness/comfort to the best), the duration of wearing respirators (percentage of wearing time both indoors and outdoors), and the health conditions (headache, dizziness, tightness of breath, tiredness, etc.) by a standardized questionnaire twice a day (i.e., 9 a.m. and 3 p.m.). The demographic characteristics including age, standing height (cm) and weight (kg) were recorded at baseline.

This study was approved by the Institutional Review Board of the School of Public Health, Fudan University (IRB# 2014-01-0473). Written informed consents were obtained from all participants before enrollment and the study was registered and approved by the ClinicalTrials.gov with the identifier NCT02238028.

2.2 The respirator

Disposable particulate respirators 8210V (3M, USA) were used in this study. These respirators are capable of filtering at least 95% of the 0.3μm non-oil particulates, meeting NIOSH N95 standards. An expiration valve was installed in the respirators. Qualitative respirator fit testing on the face-to-respirator seal was performed before the intervention study using the 3M^{TM} Qualitative Fit Test Apparatus FT-30 (3M, USA). First, the subjects wore the respirators correctly and then wore the professional testing hood on the head. A bitter agent was sprayed into the hood. If the subject did not taste the bitter agent at all, the respirators were worn tightly. Such testing was repeated three times requiring the subjects performing three different movements, including standing and slightly turning their head left and right, standing and half crouching, and standing and reading. No detection of bitter taste in any testing was considered as formally accepted.

2.3 Heart rate variability

A 12-lead continuous electrographic Holter monitor (Seer Light, GE Medical Systems Co., Ltd., USA) was installed in each participant during the 2nd 24hr period in each intervention (from 8:00 a.m. to 8:00 a.m.). A total of 8 parameters of HRV were analyzed including 4 time-domain indices and 4 frequency-domain indices. The

time-domain variables include: a) the standard deviation of the normal-to-normal interval (SDNN), estimating the overall HRV; b) the root mean square of the successive differences (rMSSD), estimating the short-term components of HRV and as a sensitive indicator of vagal tone; c) the standard deviation of the average NN intervals calculated over short periods (SDANN); and d) the proportion of successive normal NN intervals differing by more than 50 ms in the total number of NNs (pNN50). The frequency-domain parameters include high frequency (HF) power (0.15-0.4 Hz), low frequency (LF) power (0.04-0.15 Hz), very low frequency (VLF) power (0.01-0.04 Hz), and the ratio of LF and HF (LF/HF). The average heart rate and HRV parameters were analyzed by MARS Holter system (GE, USA) and were proceeded by professional clinical technologists who were blind to the study design.

2.4 Ambulatory blood pressure

A portable, non-invasive, automated BP monitoring and recording instrument (Model 90217, Spacelabs, UK) was installed on each subject during the 2nd 24hr period in each intervention (from 8:00 a.m. to 8:00 a.m.). The instrument was put over the left brachial artery and BP was measured every 15 minutes in the daytime (06:00-22:00) or every 30 minutes in the night time (22:00–06:00). During the measurement with pumping signal, the subjects were required to be free of movement until the pump stopped. At least 60 measurements (out of the total 80 measurements) were considered as an effective monitoring on the BP.

2.5 Circulating biomarkers

At the end of each intervention, participants were asked to rest in a quiet room

for half an hour. Peripheral venous blood samples were collected and centrifuged immediately. The serum were collected and stored at -80°C within 30 minutes to minimize the in-vitro changes in biomarker proteins. Five circulating biomarkers were selected for quantitative analyses because they were all significantly associated with $PM_{2.5}$ in our previous studies (Chen et al. 2015a; Chen et al. 2015b). These biomarkers included endothelin-1 (ET-1), P-selectin, vascular cell adhesion molecule-1 (VCAM-1), fibrinogen and von Willebrand factor (vWF). VCAM-1, fibrinogen, P-selectin, and vWF were measured using the Millipore MILLIPLEX MAP human cytokine/chemokine kit (Millipore Corp., Billerica, Massachusetts), while ET-1 was measured using enzyme-linked immunosorbent assays. All tests were performed according to the manufacturer's instructions.

2.6 **Environmental data**

The $PM_{2.5}$ levels were continuously monitored both indoors and outdoors simultaneously throughout the study period, using a direct-reading personal aerosol monitor (SidePak AM510, TSI Inc., St. Paul, Minnesota, USA) based on the light-scattering method. For indoor environment, we measured $PM_{2.5}$ concentrations in 2 men's dormitory rooms and 2 women's dormitory rooms. These rooms were randomly selected from a total of 10 rooms (5 men's and 5 women's). For outdoor environment, monitors were installed on the roof top of men's dormitory building. All dormitory rooms were close to each other within 50m. Before the monitoring, all devices were calibrated with a nearby national monitoring station, putting them together within 20m close to the sampling inlet of the monitoring station. The station

applied the classical tapered element oscillating microbalance (TEOM) to measure the ambient $PM_{2.5}$. In addition, temperature and relative humidity were continuously monitored and recorded by a HOBO data logger (Onset Computer Corporation, Pocasset, MA, USA) both indoors and outdoors.

2.7 Data analyses

We compared the health indicators by paired Student's t tests in the absence and presence of wearing respirators. HRV and blood biomarker data were log-transformed before regression analyses because of the approximate log-normal distribution. To account for the repeated measurements of health outcomes, we applied linear mixed-effect models to investigate the effects of wearing respirators (Chen et al. 2015a). This model allowed each subject to serve as his or her own control over time, accounting for the between-subject variations that did not change over time. The intervention was coded as a dummy variable (i.e. 1 for wearing respirator and 0 for not wearing respirator) and analyzed as a fixed-effect term in the model. Age, sex, body mass index, $PM_{2.5}$ concentration, 48-h mean temperature and 48-h mean humidity were introduced into the model as fixed-effect terms. At last, we incorporated random-effect intercepts for subjects to account for correlations between repeated measurements.

The estimates for HRV parameters and circulating biomarkers were presented as the average percentage changes and their 95% confidence intervals (CIs). The estimates for BP were presented as the average absolute changes and 95% CIs. All statistical tests were 2-sided with alpha 0.05. All analyses were conducted with the

"lme4" package of R software (version 2.15.3, R Development Core Team).

3. Results

3.1 Descriptive statistics

Six participants dropped the study in the middle due to sickness (n=2), moving to another campus (n=2) and private affairs (n=2). Therefore, 24 subjects finally completed the two periods of intervention. The average age of the 24 subjects was 23 years with males accounting for 54.2%, and the average body mass index was 22±4 kg/m^2. The scores on feelings of fitness and comfort in the study period were 6 and 5 on average, respectively, suggesting acceptable toleration of wearing the respirators. The average time of wearing respirators accounted for over 90% of their time outdoors and 82% indoors, showing a good compliance of subjects to the intervention (Figure 1).

The mean daily average concentrations of $PM_{2.5}$ were 74.2 $\mu g/m^3$ outdoors and 85.2 $\mu g/m^3$ indoors during the intervention period (Table 1), more than 3 times higher than the WHO guideline on a daily average (25 $\mu g/m^3$). The concentrations of indoor $PM_{2.5}$ were slightly higher than the outdoor $PM_{2.5}$ but the difference was not statistically significant. Considering the particulate-filtration efficiency of the respirator and the wearing time proportion, the estimated time-weighted exposure levels of $PM_{2.5}$ for subjects wearing respirators were 7.1 $\mu g/m^3$ outdoors and 19.3 $\mu g/m^3$ indoors on average. During the study period, the mean outdoor temperature and relative humidity was 12.9°C and 61%, respectively.

3.2 Effects of wearing respirators

By comparison, subjects wearing respirators had higher levels of most HRV parameters and lower levels of BP and circulating biomarkers (Table 2). The differences of HF power and pNN50% reached statistical significance. The LF/HF was higher in the absence of respirators with statistical significance.

The mixed-effect linear model showed that subjects wearing respirators had a decrease of 2.7mmHg (95%CI: 0.1, 5.2 mmHg) in systolic BP, comparing with those not wearing respirators. In the same comparison, there were increases of 12.5% (95%CI: 3.8%, 21.2%) in HF power, 3.2% (95% CI: -2.9%, 9.3%) in VLF power, 4.1% (95% CI: -2.4%, 10.7%) in SDNN, 10.9% (95% CI: 1.8%, 20.0%) in rMSSD, and 22.1% (95%CI: 3.6%, 40.7%) in pNN50% (Table 3, Figure 2). The presence of respirators was also associated with decreases of 2.6% (95% CI: -3.9%, 9.1%) in LF and 7.8% (95%CI: 3.5%, 12.1%) in LF/HF.

Wearing respirators was associated with decreases of several circulating biomarkers of inflammation (3.0% (95% CI: -23.6%,17.7%) in fibrinogen, 18.9% (95% CI: -50.7%,12.8%) in P-selectin, and 15.6% (95% CI: -36.2%,5.0%) in VCAM-1), vasoconstriction (8.6% (95% CI: -22.8%,5.6%) in ET-1) and blood coagulation (9.5% (95% CI: -30.1%,11.1%) in vWF), but all the associations were not statistically significant.

4. Discussion

By a randomized controlled crossover study design, this intervention study

demonstrated that wearing high-efficiency particulate-filtering respirators for a short time may improve HRV parameters and decrease BP levels in healthy young adults in Shanghai, China. This study was one of the few investigations evaluating the health benefits of wearing respirators under urban air pollution levels in developing countries.

Consistent with previous studies, we found that a short-term exposure to ambient PM was associated with altered HRV (Dockery 2001). For example, a study among 120 healthy young subjects in Taiwan reported significant decreases in various HRV parameters associated with increased levels of $PM_{2.5}$ (Liu et al. 2015). A recent meta-analysis of 18,667 participants enrolled in 29 studies reported an inverse relationship between parameters of HRV and exposure to PM (Pieters et al. 2012). Experimental study also supports the hypothesis that the autonomic nervous system is a potential target for the adverse effects of air pollution (Stone and Godleski 1999). Reduced HRV represents a withdrawal of cardiac vagal tone or an increase in sympathetic tone and is a predictor of poor prognosis in patients recovering from myocardial infarction or cardiac failure. Decreased HRV may further elevate the risk of cardiac arrhythmias in these at-risk patients (Odemuyiwa et al. 1991). These findings consistently showed plausible pathways by which $PM_{2.5}$ exposure affected the cardiovascular system.

In this study, we explored the effects of $PM_{2.5}$ on HRV by reducing the exposure levels through wearing high-efficiency respirators in a group of healthy young subjects. A variety of mechanistic hypotheses by which inhaled particles may affect

neural control of the heart involve both sympathetic and parasympathetic portions of autonomic nervous system (Stone and Godleski 1999). By examining both the time-domain and frequency-domain HRV parameters, the changes in HRV were predominantly observed in the HF-power band, which was mainly influenced by the parasympathetic tone. This indicated an increased contribution of parasympathetic tone to the heart autonomic function control when the particulate exposure was reduced by wearing particulate-filtering respirators. Also, the significant increase in pNN50 when wearing the respirators suggested an increased parasympathetic cardiac autonomic control in response to lower $PM_{2.5}$ exposure. On the other hand, inhaled particles may promote a systemic sympathetic stress response that leads to decreased HRV and increased ratio of LF/HF power(Stone and Godleski 1999).

Furthermore, we observed that a decrease in PM exposure was associated with lower BP levels, which was consistent with many previous findings (Brook et al. 2002; Pieters et al. 2012; Tsai et al. 2012). A panel study in Taiwan based on personal $PM_{2.5}$ measurements and ambulatory BP monitoring showed that a 10 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with significant increases in SBP by 0.81mmHg (95%CI: 0.19,1.43mmHg) and in DBP by 0.63mmHg (95%CI: 0.17,1.10mmHg) (Chang et al. 2015). In our study, we failed to observe a significant effect on DBP, which was also consistent with some previous studies (Pieters et al. 2015; Zhang et al. 2013).

Blood inflammation, coagulation and vasoconstriction have been proposed to be mainly responsible for the biological mechanisms of the cardiovascular effects of $PM_{2.5}$ (Chen et al. 2015a). We observed that wearing respirators would led to lower

level of 5 circulating biomarkers of inflammation, coagulation and vasoconstriction, although the decreases were not statistically significant. The weak effects on circulating biomarkers may be due to the relatively small sample size, shorter intervention period, relatively younger age, and incomplete control in exposure scenarios with 10%~20% time not wearing respirators. We may expect larger effects using longer intervention period, and in older or susceptible population subgroups.

The evaluation of individual intervention approaches in reducing hazards associated with $PM_{2.5}$ was crucial to public health. We found that a short-term use of respirators might result in an improvement in cardiac autonomic nervous function and a decrease in BP. The results on HRV and BP were consistent with two previous intervention studies using respirators in healthy volunteers and patients with coronary heart disease (Langrish et al. 2009; Langrish et al. 2012) in Beijing. Considering these cardiovascular health parameters together, there might be interplayed roles within them. For example, the decreased inflammatory levels might influence and cause increased HRV and further lower the BP levels, or increase HRV might benefit decreasing the BP as well. However, we did not measure nor collect the samples at different time lags and this hinted us a direction for further research.

There are several limitations in this study. First, on wearing respirators, subjects might feel increased respiration resistance which might have increased subjects' anxiety. This in turn might trigger the sympathetic nervous system tone and hence lead to an increase of LF-power. A double-blinded design by using a sham face-piece respirator would have helped remove the effect of anxiety. However, we did not have

sufficient resources to find the exactly 'same' but sham respirators. Second, we recruited healthy college students rather than those more susceptible to PM (such as patients with chronic cardiovascular diseases) to better control for potential confounding that might have been difficult to control in other study settings (e.g., indoor cooking, smoking, medication use, and individual health status). Therefore, cautions are needed to extrapolate directly our findings to other subgroups. Third, the short-term nature in this study might have led us to underestimate or miss some potential lagged health benefits attributable to respirators. Fourth, our findings were exploratory in nature because of the relatively small sample size. Fifth, exposure measurement errors were inevitable because $PM_{2.5}$ was not measured at individual level. The monitoring devices were not calibrated by gravimetric measurements and some indoor sources (e.g. human activities) were likely to influence the participants' exposure levels to $PM_{2.5}$. Sixth, we did not measure physical activity level directly, which might confound our results to some extent. Therefore, larger studies on long-term use of respirators in vulnerable populations were needed to confirm our findings in the future.

In summary, this randomized crossover study suggested that a short-term wearing of particulate-filtering respirators may obtain cardiovascular benefits in improving autonomic nervous function and lowering BP levels. Our findings provided preliminary evidence that a respirator may serve as an effective and practical tool to protect individual cardiovascular health from particulate air pollution in a developing country with severe air pollution problems.

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Table 1. Air pollutant concentrations and weather conditions (daily 24-hr means, 4 days) during the intervention periods.

Air pollutants	Mean	SD	Min	P25	Median	P75	Max
Outdoor							
$PM_{2.5}$ ($\mu g/m^3$)	74.2	38.3	32.0	51.0	61.5	84.0	227.0
NO_2 ($\mu g/m^3$)	49.1	23.8	16.6	30.1	42.3	62.3	107.6
SO_2 ($\mu g/m^3$)	11.1	5.0	5.2	6.9	10.3	13.5	32.2
CO (mg/m^3)	0.4	0.2	0.1	0.2	0.3	0.4	1.3
Temperature (°C)	12.9	4.6	6.4	10.0	13.1	14.7	21.9
Humidity (%)	61.0	17.4	43.0	44.3	57.0	80.3	83.0
Indoor							
$PM_{2.5}$ ($\mu g/m^3$)	85.2	43.6	26.7	54.0	73.0	100.3	240.7
Temperature (°C)	20.9	1.4	15.5	20.0	21.0	22.2	25.9
Humidity (%)	47.6	7.8	27.4	41.2	48.9	51.5	78.3

Abbreviations: $PM_{2.5}$, particulate matter with the aerodynamic diameter equal to or less than 2.5 μm; SO_2, sulfur dioxide; NO_2, nitrogen dioxide; CO, carbon monoxide;P25, the 1st interquartile value of $PM_{2.5}$ concentration; P75, the 3rd interquartile value of $PM_{2.5}$ concentration.

The outdoor $PM_{2.5}$ measurements were performed in 4 days and the indoor environment was monitored in 4 days in 4 dormitory rooms.

Table 2. Comparisons (means and standard deviations) on various cardiovascular outcomes in subjects wearing respirators or not during the intervention periods

Parameters	Respirator (N=24)	Non-respirator (N=24)	P
Blood pressure			
SBP(mmHg)	107.3±8.0	109.0±7.4	0.097
DBP(mmHg)	70.0±5.0	70.8±4.8	0.235
Heart rate variability			
LF power(ms^2)	899.4±601.3	838.5±562.4	0.250
HF power(ms^2)	519.7±371.0**	416.6±296.6**	0.010
VLF power(ms^2)	1684.6±875.7	1623.1±1006.5	0.448
LF/HF	1.4±0.3**	1.5±0.3**	0.004
SDNN(ms)	177.5±29.9	173.2±40.1	0.467
SDANN(ms)	160.7±28.9	156.0±37.8	0.421
rMSSD(ms)	49.0±13.3	44.7±14.8	0.062
pNN50(%)	24.0±9.9*	20.5±10.5*	0.029
Circulating Biomarkers			
Fibrinogen(μg/ml)	2.5±1.3	2.5±1.3	0.801
P- selectin(ng/ml)	164.0±2.0	200.3±1.5	0.185
VCAM-1(ng/ml)	1480.3±1.5	1808.0±1.6	0.138
ET-1(pg/ml)	109.9±1.6	121.5±1.6	0.172
vWF(μg/ml)	24.5±1.3	27.1±1.3	0.337

*Differences with $P<0.05$, **$P<0.01$

Abbreviations: Bpm, beat per minute; SBP, systolic blood pressure; DBP, diastolic blood pressure; LF, low frequency; HF, high frequency; VLF, very low frequency; LF/HF, the ratio of LF and HF; SDNN, the standard deviation of the normal-to-normal interval; SDANN, the standard deviation of the average NN intervals calculated over short periods; rMSSD, the root mean square of the successive differences; pNN50, the proportion of successive normal NN intervals differing by more than 50 ms in the total number of NNs; ET-1, endothelin-1; VCAM-1, vascular cell adhesion molecule-1; vWF, von Willebrand factor

Table 3. Percent change (mean%, 95% CI) or differences (for BP) in various cardiovascular outcomes comparing the presence of respirators with the absence of respirators.

Parameters	Change,%	95%CI	P value
Blood pressure†			
SBP(mmHg)	-2.7	(-5.2,-0.1)*	0.049
DBP(mmHg)	-0.5	(-2.5,1.5)	0.622
Heart rate variability			
LF power(ms^2)	-2.6	(-9.1,3.9)	0.262
HF power(ms^2)	12.5	(3.8,21.2)*	0.012
VLF power(ms^2)	3.2	(-2.9,9.3)	0.313
LF/HF	-7.8	(-12.1,-3.5)*	0.001
SDNN(ms)	4.1	(-2.4,10.7)	0.231
SDANN(ms)	5.0	(-2.5,12.6)	0.207
rMSSD(ms)	10.9	(1.8,20.0)*	0.032
pNN50(%)	22.1	(3.6,40.7)*	0.037
Circulating biomarkers			
Fibrinogen(ug/ml)	- 3.0	(-23.6,17.7)	0.765
P- selectin(ng/ml)	-18.9	(-50.7,12.8)	0.192
VCAM-1(ng/ml)	-15.6	(-36.2, 5.0)	0.122
ET-1(pg/ml)	- 8.6	(-22.8,5.6)	0.168
vWF(ug/ml)	- 9.5	(-30.1,11.1)	0.331

Abbreviations: The same as Table 2.

Linear mixed-effect models were applied to investigate the effects of wearing respirators, with the adjustment of age, gender, body mass index, $PM_{2.5}$ concentration, 48-h mean temperature and 48-h mean humidity.

† The estimated effects for BP were the absolute difference in mmHg comparing the presence of respirators with the absence of respirators.

Figure 1. Proportion of time on wearing respirators outdoors and indoors.

Figure 2. Percent change of various cardiovascular outcomes comparing the presence of respirators with the absence of respirators.

Abbreviations: The same as Table 2.

Figure 1.

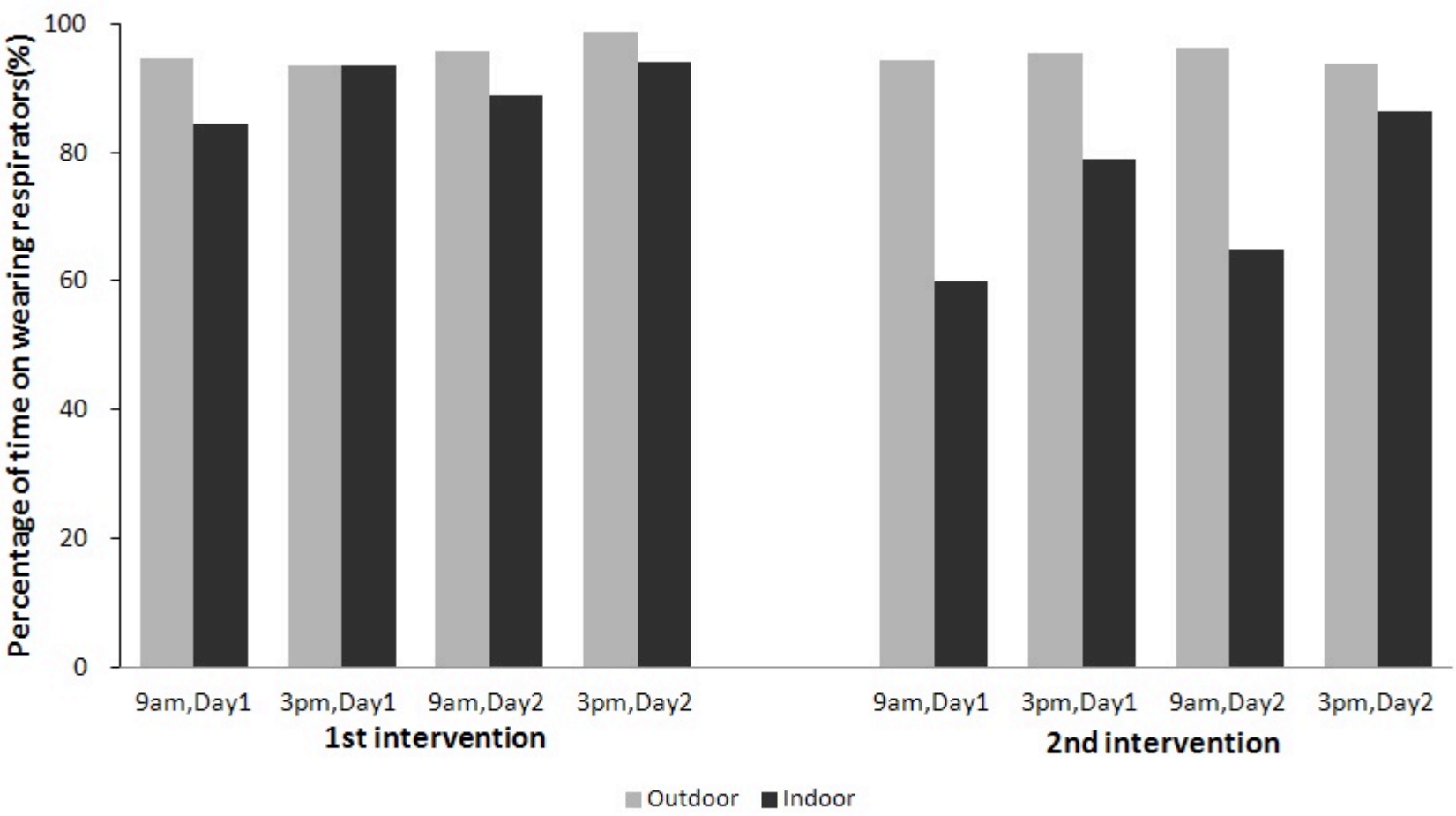
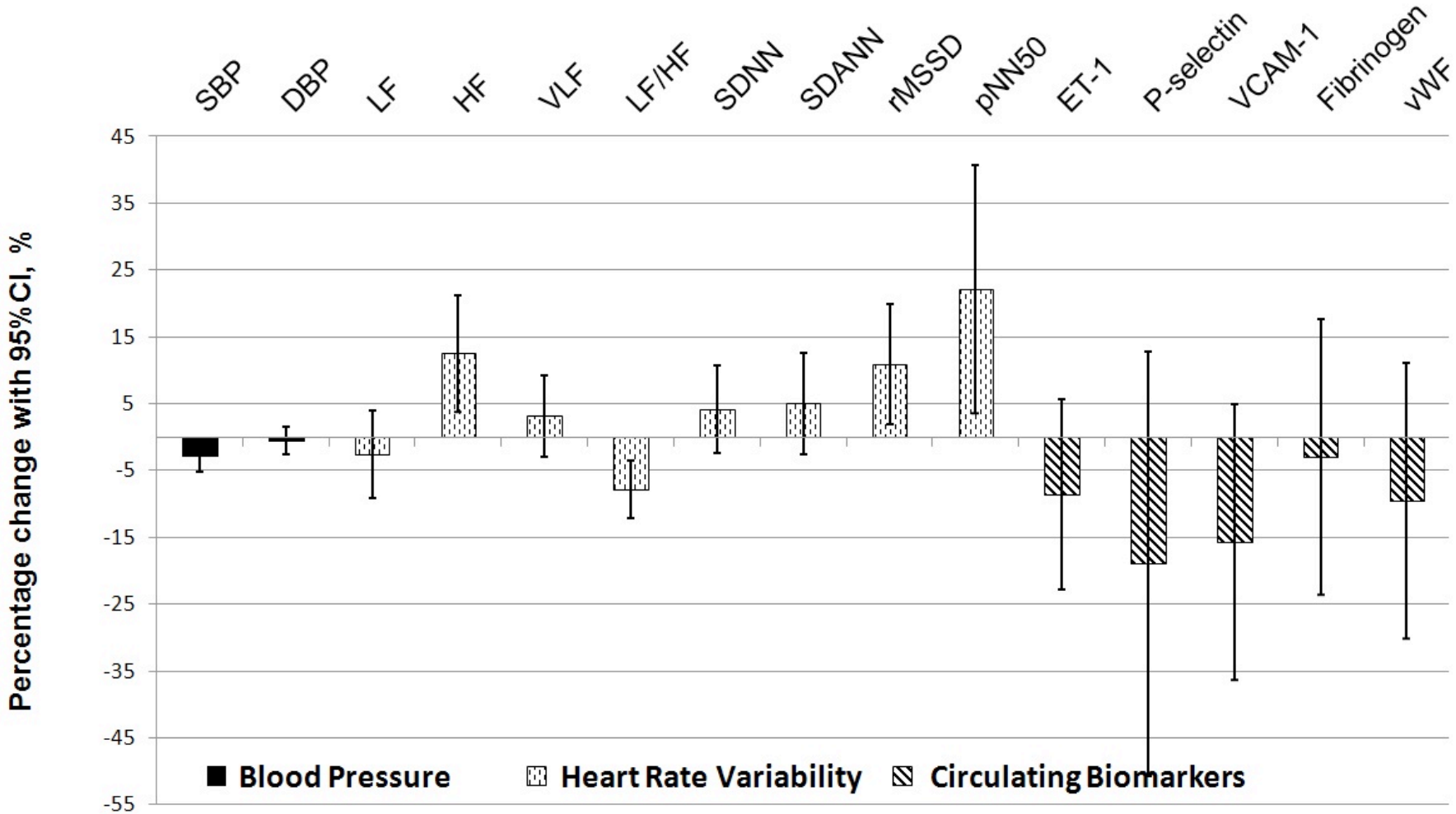

Percentage of time on wearing respirators(%)
100
80
60
40
20
0
9am,Day1
3pm,Day1
9am,Day2
3pm,Day2
1st intervention
9am,Day1
3pm,Day1
9am,Day2
3pm,Day2
2nd intervention
Outdoor
Indoor

Figure 2.


SBP
DBP
LF
HF
VLF
LF/HF
SDNN
SDANN
rMSSD
pNN50
ET-1
P-selectin
VCAM-1
Fibrinogen
vWF
45
35
25
15
5
-5
-15
-25
-35
-45
-55
Percentage change with 95% CI, %
Blood Pressure
Heart Rate Variability
Circulating Biomarkers